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Addendum to Seismic Verification of Nuclear Plant Equipment Anchorage

Volume 1: Development of Anchorage Guidelines (Revision 1)

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REPORT SUMMARY

Addendum to Seismic Verification of Nuclear Plant Equipment Anchorage

Volume 1: Development of Anchorage Guidelines (Revision 1)

EPRI anchorage guidelines provide utility engineers with comprehensive procedures and criteria for evaluating seismic adequacy of a wide variety of equipment anchorage types. These guidelines are the basis and principal reference for the anchorage evaluation procedures in the Seismic Qualification Utility Group (SQUG) Generic Implementation Procedure (GIP) for resolution of Unresolved Safety Issue (USI) A-46. This addendum presents allowable strength criteria for a group of nondatabase bolts that were the subject of a testing program in 1991.

INTEREST CATEGORIES

Nuclear seismic risk, design, and qualification
Nuclear component reliability

KEYWORDS

Earthquakes
Seismic effects
Seismic qualification
Electrical equipment
Mechanical equipment
Equipment anchorage

BACKGROUND Seismic evaluations of older nuclear power plants have indicated that equipment anchorage is one of the most important engineering features by which seismic capacity of equipment can be readily and practically improved. Equipment anchorage has become the focal point of walkdown procedures developed by SQUG and EPRI for resolution of USI A-46 and seismic aspects of NRC Severe Accident Policy issues. Because of the variety of available anchorage devices, a generic assessment procedure is needed for resolution of each of these issues.

OBJECTIVE To develop guidelines for the seismic evaluation of equipment anchorage in existing nuclear power plants.

APPROACH For the original report, the research team collected test data on shear and pullout capacities of expansion anchors and developed allowable loads with appropriate safety factors. For cast-in-place bolts and welds, they adopted existing industry guidelines. The team developed capacity reduction factors for various installation parameters such as close spacing and edge distance. They also formulated two alternative procedures for inspecting and evaluating bolts in a plant, including checklists and screening tables for different types of components. In the revision, the same team expanded the database to include a wider variety of bolt types and conducted static pull tests to update and improve the capacity reduction factors. They also developed a computer program for rapid in-plant evaluation of anchor systems and added consideration of phenomena such as prying action, preload relaxation, and overall system stiffness.

RESULTS EPRI report NP-5228-M, Revision 1, summarizes the guidelines. Report NP-5228-SL, Revision 1, consists of four volumes. Volume 1 contains the guidelines. Volume 2 provides a workbook for field evaluation. Volume 3 offers a user's manual for the computer program, EPRI/Blume Anchorage Code (EBAC), used for comparison of demand and capacity. Volume 4 describes a comprehensive calculation and inspection procedure for tank and heat exchanger anchorage. This addendum provides revised knockdown factors (KDF) for a group of nondatabase bolts reported in Volume 1. KDFs for most of these bolt types have increased; however, some have decreased. The anchorage criteria in these four volumes have been incorporated into the SQUG GIP for resolution of USI A-46. The revised KDFs will be considered for incorporation in Revision 3 of the GIP.

EPRI PERSPECTIVE It has been widely believed that equipment anchorage should be the focus of any plant evaluation to assess seismic adequacy or improve plant seismic safety. This has been evident in trial evaluations that show (1) most "outlier" conditions are anchorage related and relatively easy and inexpensive to resolve, and (2) upon resolution, the anchorage capacity can be substantially in excess of design basis earthquake loads. This report, along with NP-5223, Revision 1, and NP-7147, which provide generic equipment ruggedness spectra (GERS), and report NP-7418, which describes procedures to assess electrical relay seismic functionality, complements the seismic experience data collected by SQUG and EPRI to form the basis for cost-effective resolution of USI A-46.

PROJECT

RP2925-01

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Volume 1: Development of Anchorage Guidelines
Revision 1

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NOTICE TO RECIPIENTS OF THIS ADDENDUM

As a result of recently conducted tests, this document recommends changes to certain SQUG knock-down factors, (KDF), which are defined in EPRI report NP5228, Rev 1, Vol 1. For four types of bolts this report recommends an increase in the KDF from 0.6 to 0.75. It also recommends that the KDF be reduced from 0.75 to 0.5 for all diameters of the Wej-It Wedge bolt and from 0.6 to 0.5 for the 3/8" diameter Hilti Sleeve bolt.

Further study of industry data is being conducted to determine if the test results for the Wej-It Wedge are generically applicable. Depending on the outcome of these studies, some relief for the Wej-It Wedge may be realized.

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DEVELOPMENT OF ALLOWABLE STRENGTH CRITERIA FOR NON-DATA BOLTS

Purpose

The purpose of this Addendum is to develop allowable strength criteria for a group of so-called non-database bolts that were the subject of a testing program conducted by Kleinfelder Labs in 1991.

Background

From 1984 to 1986, EPRI compiled a database of static tension and shear tests on expansion anchor bolts and used these data to justify allowable strength criteria based upon the overall sample mean divided by 3. For each diameter of concern (e.g., 3/8", 1/2", 5/8", etc.) the allowable load was taken as the overall mean for the bolts of that diameter divided by 3.

Subsequently, it was recognized that there were bolts made by other manufacturers that were not well represented or, in some cases, totally absent from the EPRI bolt test database. There was concern that the allowable loads contained in the EPRI criteria might not be appropriate for the so-called non-database bolts.

This concern was first addressed by obtaining readily available strength data for these non-database bolts from several convenient sources. Data were obtained from evaluation reports published by the International Conference of Building Officials (ICBO) and manufacturer's catalogs in instances where ICBO data were not available. These data were in the form of average ultimate pullout and shear strength of each diameter for each bolt type. These data were used to calculate Capacity Ratios (CR) and Knock-Down Factors (KDF) for the non-database bolts as follows:

$$CR = \frac{\text{Average Ultimate Pullout Strength from Published Data}}{\text{EPRI Mean Pullout Strength for } f'_c \geq 4{,}000 \text{ psi}}$$

where "Published Data" refers to data obtained from ICBO reports or manufacturer's catalogs.

A CR (minimum) was calculated for each diameter for each type of non-database bolt for both shear and tension. KDFs were assigned for each type of non-database bolt using the following ground rules:

KDF = 1	for	CR (Minimum) $\geq$ 0.8
KDF = 0.75	for	0.6 $\leq$ CR (Minimum) < 0.8
KDF = 0.6	for	0.48 $\leq$ CR (Minimum) < 0.6

A single value of KDF was assigned to each type of non-database bolt using the minimum CR considering the CRs calculated for all diameters and for both shear and tension loading. In every case, the KDF for each non-database bolt was controlled by the CR (minimum) for tension loading.

The allowable strengths for the non-database bolts were taken as the appropriate KDF for that bolt type times the EPRI Mean/3. Further background on this methodology and the results of the CR (minimum) and KDF evaluations are given on pages 2-30 through 2-38 of the main EPRI Report, Volume 1.

Testing Program

In 1991, EPRI sponsored a supplemental testing program for five bolt types: Star Steel, Star Stud, WEJ-IT Stud, WEJ-IT Wedge, and Hilti Sleeve. Tests were performed at two independent test labs: Kleinfelder (Reference 1) and Techmar (Reference 2). The vast majority of the tests were performed by Kleinfelder. Confirmatory tests were performed by Techmar.

The purpose of these tests was to determine whether or not the results could be used to justify higher KDFs for this group of non-database bolts.

For each bolt type, a range diameter was tested. The tests were incremental static tension load tests to failure. In the Kleinfelder test program, a total of 215 tests were successfully performed; typically ten tests were performed for each diameter. Concrete compression strengths for the Kleinfelder tests varied from 3,940 psi to 4,760 psi. The results have been reported (Reference 1) in terms of a tabulation of the failure pullout load for each test, and the mean and standard deviation for each diameter for each bolt type.

The confirmatory tests performed by Techmar (Reference 2) consisted of 15 tests, three each on the following bolt types: 1/2-inch diameter Hilti Sleeve, 1/2-inch diameter WEJ-IT Wedge, 1-inch diameter WEJ-IT Stud (a.k.a. Ankr-tite), 1/2-inch diameter WEJ-IT Stud (a.k.a. Ankr-tite), and 1/2-inch diameter Star Stud. All tests were performed in concrete having a compressive strength of 4,387 psi. The Techmar program was conducted to provide independent verification of the results obtained by Kleinfelder.

Summary of Data

A summary of the data obtained from the Kleinfelder test program is provided in Table 1. In the following table, the CR has been calculated by dividing the mean of the Kleinfelder test results by the main EPRI mean at $f'_c \geq 4{,}000$ psi. A comparison of these results with the data given in Table 2.15 of the main EPRI Anchorage Report indicates that the results in Table 1 are not significantly greater than either ICBO or manufacturer's values. For the WEJ-IT Wedge, the results of the testing appear to be only about 50% of the ICBO values.

Table 1
Summary of Test Data
From Kleinfelder (Reference 1)

Diameter (in).	3/8"	1/2"	5/8"	3/4"	7/8"	1"	CR (Minimum)
Star Steel							
Test Mean (kip)	2.805	5.545	8.605	8.180	—	—	0.58
Test S.D. (kip)	0.395	0.520	0.515	1.270	—	—	
Test C.O.V.	0.14	0.09	0.06	0.16	—	—	
CR	0.64	0.81	0.90	0.58	—	—	
Star Stud							
Test Mean (kip)	2.560	3.790	7.580	10.950	—	—	0.55
Test S.D. (kip)	0.310	0.520	0.910	0.620	—	—	
Test C.O.V.	0.12	0.14	0.12	0.06	—	—	
CR	0.58	0.55	0.80	0.78	—	—	
WEJ-IT Stud							
Test Mean (kip)	2.795	4.215	6.295	9.055	—	14.430	0.61
Test S.D. (kip)	0.405	0.430	0.690	0.285	—	3.735	
Test C.O.V.	0.14	0.10	0.11	0.04	—	0.26	
CR	0.64	0.61	0.66	0.64	—	0.69	
WEJ-IT Wedge							
Test Mean (kip)	1.925	2.920	4.060	5.880	8.687	12.320	0.42
Test S.D. (kip)	0.430	0.455	0.640	0.920	1.33	1.430	
Test C.O.V.	0.22	0.16	0.16	0.16	0.15	0.12	
CR	0.44	0.43	0.43	0.42	0.48	0.59	
Hilti Sleeve							
Test Mean (kip)	2.230	4.555	6.365	—	—	—	0.51
Test S.D. (kip)	0.648	1.320	1.105	—	—	—	
Test C.O.V.	0.29	0.29	0.17	—	—	—	
CR	0.51	0.66	0.67	—	—	—	

In Table 1 the CR has been calculated as follows:

$$CR = \frac{\text{Kleinfelder Mean}}{\text{EPRI Mean}}$$

Focusing on the test means and the CR values in this table, and the previously defined ground rules for assigning KDFs based on CRs, it is apparent that these results justify increasing the KDFs from 0.6 to 0.75 for some bolts of certain diameters. However, these results also suggest a reduction in the KDF for the WEJ-IT Wedge for all diameters. (Note that the main EPRI report Table 2.15 assigns the WEJ-IT Wedge a KDF = 0.75 based on CR = 0.67.)

Evaluation of Test Results

Using the previously defined ground rules to assign KDFs for the bolts in Table 1 may be an overly conservative approach. Recall that the main EPRI Anchorage Report developed these ground rules for the purpose of including bolts for which only minimal test data existed (typically only three tests per diameter for each manufacturer and type). The new data (i.e., Table 1), typically based on 10 tests per diameter for each manufacturer and type, are similar to the data sets included in the original EPRI test database. Therefore it is appropriate to develop allowable values for the new bolts (i.e., those in Table 1) using essentially the same approach as that used for the bolts originally included in the EPRI database.

Basis for Allowable Values in the Original Database

The original EPRI database included a large number of tests on a variety of bolts. The allowable values derived from the original EPRI database were obtained as follows:

$$\text{Allowable Value} = \frac{\text{Overall Mean}}{2 \times 1.5}$$

Both the Allowable Value and the Overall Mean were on a diameter-by-diameter basis. The logic for selecting the factors of 2 and 1.5 in the evaluation of the original EPRI database is as follows:

Factor of 2: This factor was derived based on the variability of the test data in the original database. Specifically, the factor of 2 was selected because on an aggregate basis, only 1.4% of the pullout test data for well installed bolts with KDF = 1 were less than the overall mean divided by 2, and on a diameter-by-diameter basis a maximum of only 3% of the tests were below the overall mean over 2 (see Table 2.9 of the original report).

Factor of 1.5: This factor was included to account for field installation factors that were not represented in the laboratory test data upon which the overall mean was based. This factor was introduced to reduce the allowable values to account for field installation conditions.

KDFs for New Bolts for Pullout Loading

In establishing KDF values for the new bolts (Table 1 of the Addendum) the overall objective is to be consistent with the basis for the allowable values in the original EPRI database. This objective can be accomplished by choosing a KDF based upon several criteria, including:

$$\text{1\% to 3\% of the New Test Data} \leq \frac{\text{Overall Mean}}{2} * \text{KDF}$$

In this expression, the "Overall Mean" refers to the Overall Mean of the original test data, that is, the original EPRI test database. The "New Test Data" refers to individual test results reported in References 1 and 2 on a diameter-by-diameter basis. The factor of 2 and the approximate 1% to 3% range have been selected to be consistent with the approach used to establish the original allowable values. The KDF in the above expression should be used to determine allowable values for the new bolts (Table 1) from the allowable values of the bolts in the original EPRI database.

Based on this criterion, the new test data were initially evaluated and screened as follows:

$$\text{Test Data} = \frac{\text{Overall Mean}}{2} * \text{KDF}$$

$$\frac{\text{KDF}}{2} = \frac{\text{Test Data}}{\text{Overall Mean}}$$

Where possible, a trial KDF for each bolt type was first selected such that no more than 1% to 3% of the test data have a Test Data-to-Overall Mean ratio of less than the trial KDF/2.

As a second screen, the trial KDF was tested against the median ratio of Test Data/Overall Mean. Ideally, the trial KDF should be about equal to or not much greater than the median ratio. If the trial KDF was much greater than the median ratio, the trial KDF was scaled back on a judgmental basis to be closer to the median ratio. In performing this scaling, the ratio value, which exceeded one-third of the test data, was also considered as a judgmental factor to indicate the variability of the test data. Specifically, if the median ratio was much greater than the 1/3 ratio, this was considered a broad distribution, implying that the KDF would need to be close to the median value.

The ratios of Test Data/Overall Mean are summarized in Appendix I of this Addendum. The data contained in Appendix I of this Addendum include tests from Kleinfelder (Reference 1) and Techmar (Reference 2).

Two tests included in Appendix I of this Addendum, specifically Tests 5 and 7 of the 1/2-inch diameter Hilti Sleeve Bolt test series, warrant further discussion. The bolts upon which these tests were performed were damaged during installation, and the test results were quite low compared to other tests in the same series.

Like all wedge anchors, the torque applied to set these anchors caused the anchor to be partially extracted from the hole. In these cases, this extraction caused the end of the sleeve to raise above the surface of the concrete. The combination of the installation torque and the exposed sleeve caused a distortion of the sleeve and resulted in damage to the sleeve during the setting process.

Even with their damaged conditions, Bolts 5 and 7 of the 1/2-inch diameter series were able to resist some pullout loads before failure. However, as noted above, the failure loads for these tests are considerably lower than the other tests in the series.

The installation difficulties experienced during these tests would not be expected in actual field installations of the Hilti Sleeve. The extraction of the sleeve above the surface of the concrete during setting could not be tolerated in field conditions due to the resulting fit-up problems with base plates and/or equipment base framing. In all likelihood, actual field installations would involve drilling deeper holes such that the application of the setting torque would not cause the sleeve to protrude above the surface of the concrete. Having the sleeve below the concrete surface would mitigate torque damage to the sleeve and results in better performance. Nevertheless, anchorages involving all sleeve bolts should be inspected to determine the possibility of an exposed and damaged sleeve.

For the reasons discussed above, Tests 5 and 7 of the 1/2-inch diameter Hilti Sleeve series were not rigorously considered in setting the trial KDFs. However, these tests were included in aggregating the data (Table 3) to determine the number of tests less than the allowable capacity.

Observations from Appendix I of this Addendum are as follows:

For Star Steel only one test out of 40 (2.5%) has a ratio as low as 0.38. The median ratio is 0.74, and one-third of the data falls below 0.64. Therefore, the KDF for Star Steel should be about 2 x 0.38 ≅ 0.75.

For Star Stud only one test in 42 (2.4%) has a ratio as low as 0.42, suggesting a trial KDF of about 2 x .42 ≅ 0.8. However, the median ratio (0.69) is significantly less than the trial KDF. Considering the 1/3 ratio is 0.6 (relatively close to the median) the KDF for Star Stud is scaled back to KDF = 0.75.

For WEJ-IT Stud, only two tests out of 56 (3.6%) have a ratio as low as 0.5, suggesting a trial KDF somewhat less than 2 x 0.5 ≅ 1.0. However, the median ratio (0.64) is significantly less than the trial KDF. The 1/3 ratio (0.61) is quite close to the median, suggesting a tight distribution. Based on judgment, a KDF = 0.75 is assigned to WEJ-IT Stud.

For WEJ-IT Wedge, two tests out of 63 (3.2%) have a ratio of less than or equal to 0.26, suggesting a trial KDF of about 2 x 0.26 ≅ 0.50. The trial KDF is greater than the median ratio (0.45). Considering that the 1/3 ratio (0.42) is quite close to the median, the KDF for WEJ-IT Wedge is taken as KDF = 0.5.

For the Hilti Sleeve, it is appropriate to separate the data for the 3/8-inch diameter bolts from bolts of greater diameter because the 3/8-inch data have different characteristics than the other data. For the 3/8-inch diameter, one test out of 13 (7.7%) has a ratio as low as 0.3, suggesting a trial KDF less than 0.6. In addition, the median ratio is 0.46. The 1/3 ratio for this data set is at a value of 0.43, suggesting a tight distribution. On a judgmental basis, KDF = 0.5 is set for 3/8-inch Hilti Sleeve.

For 1/2- and 5/8-inch diameter Hilti Sleeve bolts, only one test out of 16 (6.25%) is as low as 0.54, implying a trial KDF somewhat less than KDF = 1.0. (This observation discounts Tests 5 and 7 of the 1/2-inch series.) However, both the median ratio (0.69) and the 1/3 ratio (0.62) suggest the need to scale back the KDF to a lower value. A KDF = 0.75 is set for both of these on a judgmental basis.

The pullout KDFs determined in the previous paragraphs are summarized as follows:

	Pullout KDF
Star Steel	0.75
Star Stud	0.75
WEJ-IT Stud	0.75
WEJ-IT Wedge	0.5
Hilti Sleeve (3/8-inch)	0.5
Hilti Sleeve (1/2-to 5/8-inch)	0.75

As a further test of the recommended KDFs, it is appropriate to examine the number and percentage of actual tests that fall below

$$\frac{\text{KDF} \times \text{Overall Mean}}{2}$$

for the new bolts as compared to the number and percentage of tests that fell below the Overall Mean divided by 2 for the original EPRI test database. For this comparison, the Overall Mean is taken from Table 2.6 of the original report, for F'_C = 4000 psi. Appendix II to this Addendum lists all the new tests (derived from References 1 and 2). These tests have been sorted by diameter and type, and ordered by increasing pullout value. The test values in each category have been compared to their respective $\frac{\text{KDF} \times \text{Overall Mean}}{2}$. The results of this comparison, summarized in Table 2 of this Addendum, indicate that only two test data points from the new test database (232 samples) are less than the pullout capacity. When the original and new data are combined, the maximum percentages of tests that are less than their respective $\frac{\text{KDF} \times \text{Overall Mean}}{2}$ on a diameter-by-diameter basis and on an aggregate basis are 2.6% and 1.3%. These values are consistent with the overall objectives of establishing KDFs for the new bolts. Thus it is concluded that the KDFs for the new bolts provide a reasonable basis for evaluation that is consistent with the original EPRI criteria.

Table 2

Number and Percentage of Bolt Tests Less Than $\frac{\text{KDF} \times \text{Overall Mean}}{2}$

	Original Data		**New Data (References 1 & 2)**		**Combined Data**		
Diameter -inch	#Tests	#Tests L.T. $\frac{M}{2}$	#Tests	#Tests L.T. $KDF*\frac{M}{2}$	#Tests	#Tests L.T. $KDF*\frac{M}{2}$	%Tests L.T. $KDF*\frac{M}{2}$
3/8	99	1	53	1	152	2	1.3%
1/2	172	5	59	1	231	6	2.6%
5/8	155	3	47	0	202	3	1.5%
3/4	190	1	40	0	230	1	0.4%
7/8	47	0	10	0	57	0	0
1	35	0	23	0	58	0	0
Total	698	10	232	2	930	12	1.3%

L.T. = less than

KDFs for New Bolts for Shear Loading

The discussion above refers to the derivation of KDF values for the new bolts for pullout loading. The purpose of this section is to determine KDF values for the same bolts for shear.

The approach to determining KDFs for shear for the new bolts is exactly the same as that described in the main body of the EPRI report. Specifically, a capacity ratio CR was determined for each bolt type on a diameter-by-diameter basis using previously published data (e.g., ICBO reports). KDFs were assigned for shear using the ground rules given in the original report and previously stated in this Addendum. The results are as follows:

	Shear KDF
Star Steel	1.0
Star Stud	0.75
WEJ-IT Stud	1.0
WEJ-IT Wedge	0.75
Hilti Sleeve	1.0

Summary of KDFs for New Bolts

A summary of the recommended KDFs for new bolts is as follows:

	Pullout KDF	Shear KDF
Star Steel	0.75	1.0
Star Stud	0.75	0.75
WEJ-IT Stud	0.75	1.0
WEJ-IT Wedge	0.5	0.75
Hilti Sleeve (3/8-inch)	0.5	1.0
Hilti Sleeve (1/2- to 5/8-inch)	0.75	1.0

If the bolt type is unknown, the following recommendations apply (except for WEJ-IT Wedge):

Bolt Diameter = 3/8-inch, use KDF = 0.5 for pullout and KDF = 0.75 for shear

Bolt Diameter > 3/8-inch, use KDF = 0.75 for pullout and KDF = 0.75 for shear

Note that the WEJ-IT Wedge can be distinguished from all other bolts by the two vertical slots cut on each side of the bolt parallel to the longitudinal axis of the bolt.

The KDFs given in this Addendum supersede the KDFs given in Table 2.15 of the original EPRI report for the same type and size of bolt. These new KDFs shall be used in the same manner as the original KDFs given in the main body of the EPRI report.

References

1. Kleinfelder, Inc., *Concrete Expansion Anchor Testing in Connection with the URS/EPRI Anchorage Study*, January 1991.

2. Techmar, Inc., *Report of Expansion Anchor Tests Conducted for URS Consultants, Inc.*, October 1991.

APPENDIX I

Test	Manu-facturer	Bolt Type	Diam. (in)	Test Data Pullout (K)	EPRI Overall Mean (K)	RATIO	
K	STAR	STEEL	0.750	5.30	14.07	0.38	1 Test iin 40<=0.38
K	STAR	STEEL	0.750	6.72	14.07	0.48	
K	STAR	STEEL	0.375	2.21	4.39	0.50	
K	STAR	STEEL	0.375	2.21	4.39	0.50	
K	STAR	STEEL	0.750	7.94	14.07	0.56	
K	STAR	STEEL	0.375	2.51	4.39	0.57	
K	STAR	STEEL	0.750	8.34	14.07	0.59	
K	STAR	STEEL	0.750	8.55	14.07	0.61	
K	STAR	STEEL	0.750	8.55	14.07	0.61	
K	STAR	STEEL	0.375	2.71	4.39	0.62	
K	STAR	STEEL	0.375	2.73	4.39	0.62	
K	STAR	STEEL	0.750	8.75	14.07	0.62	
K	STAR	STEEL	0.750	8.95	14.07	0.64	
K	STAR	STEEL	0.750	9.12	14.07	0.65	
K	STAR	STEEL	0.750	9.56	14.07	0.68	
K	STAR	STEEL	0.375	2.99	4.39	0.68	
K	STAR	STEEL	0.375	3.08	4.39	0.70	
K	STAR	STEEL	0.375	3.12	4.39	0.71	
K	STAR	STEEL	0.375	3.25	4.39	0.74	
K	STAR	STEEL	0.375	3.25	4.39	0.74	
K	STAR	STEEL	0.500	5.10	6.87	0.74	
K	STAR	STEEL	0.500	5.10	6.87	0.74	
K	STAR	STEEL	0.500	5.10	6.87	0.74	
K	STAR	STEEL	0.500	5.10	6.87	0.74	
K	STAR	STEEL	0.500	5.10	6.87	0.74	
K	STAR	STEEL	0.500	5.50	6.87	0.80	
K	STAR	STEEL	0.625	7.94	9.51	0.83	
K	STAR	STEEL	0.625	7.94	9.51	0.83	
K	STAR	STEEL	0.500	5.91	6.87	0.86	
K	STAR	STEEL	0.625	8.34	9.51	0.88	
K	STAR	STEEL	0.625	8.34	9.51	0.88	
K	STAR	STEEL	0.625	8.34	9.51	0.88	
K	STAR	STEEL	0.500	6.11	6.87	0.89	
K	STAR	STEEL	0.500	6.15	6.87	0.90	
K	STAR	STEEL	0.500	6.32	6.87	0.92	
K	STAR	STEEL	0.625	8.75	9.51	0.92	
K	STAR	STEEL	0.625	8.95	9.51	0.94	
K	STAR	STEEL	0.625	8.95	9.51	0.94	
K	STAR	STEEL	0.625	8.95	9.51	0.94	
K	STAR	STEEL	0.625	9.56	9.51	1.01	

APPENDIX I

Test	Manu-facturer	Bolt Type	Diam. (in)	Test Data Pullout (K)	EPRI Overall Mean (K)	RATIO	
K	STAR	STUD	0.500	2.89	6.87	0.42	1 Test in 42<=0.42
K	STAR	STUD	0.500	3.21	6.87	0.47	
K	STAR	STUD	0.375	2.07	4.39	0.47	
K	STAR	STUD	0.500	3.27	6.87	0.48	
K	STAR	STUD	0.375	2.31	4.39	0.53	
K	STAR	STUD	0.500	3.66	6.87	0.53	
K	STAR	STUD	0.375	2.35	4.39	0.54	
K	STAR	STUD	0.375	2.39	4.39	0.54	
K	STAR	STUD	0.375	2.39	4.39	0.54	
K	STAR	STUD	0.500	3.88	6.87	0.56	
K	STAR	STUD	0.500	4.04	6.87	0.59	
K	STAR	STUD	0.500	4.04	6.87	0.59	
K	STAR	STUD	0.500	4.08	6.87	0.59	
T	STAR	STUD	0.500	4.09	6.87	0.60	
K	STAR	STUD	0.375	2.66	4.39	0.61	
K	STAR	STUD	0.375	2.71	4.39	0.62	
K	STAR	STUD	0.375	2.71	4.39	0.62	
K	STAR	STUD	0.500	4.42	6.87	0.64	
K	STAR	STUD	0.500	4.42	6.87	0.64	
K	STAR	STUD	0.375	2.88	4.39	0.66	
K	STAR	STUD	0.625	6.52	9.51	0.69	
K	STAR	STUD	0.625	6.52	9.51	0.69	
K	STAR	STUD	0.750	9.83	14.07	0.70	
K	STAR	STUD	0.750	9.92	14.07	0.71	
K	STAR	STUD	0.625	6.72	9.51	0.71	
K	STAR	STUD	0.375	3.12	4.39	0.71	
K	STAR	STUD	0.625	6.92	9.51	0.73	
K	STAR	STUD	0.750	10.98	14.07	0.78	
K	STAR	STUD	0.750	10.98	14.07	0.78	
K	STAR	STUD	0.750	10.98	14.07	0.78	
K	STAR	STUD	0.750	10.98	14.07	0.78	
K	STAR	STUD	0.750	11.19	14.07	0.80	
K	STAR	STUD	0.750	11.19	14.07	0.80	
T	STAR	STUD	0.500	5.51	6.87	0.80	
K	STAR	STUD	0.750	11.59	14.07	0.82	
K	STAR	STUD	0.625	7.94	9.51	0.83	
K	STAR	STUD	0.625	7.94	9.51	0.83	
K	STAR	STUD	0.750	11.79	14.07	0.84	
T	STAR	STUD	0.500	5.78	6.87	0.84	
K	STAR	STUD	0.625	8.35	9.51	0.88	
K	STAR	STUD	0.625	8.55	9.51	0.90	
K	STAR	STUD	0.625	8.75	9.51	0.92	

APPENDIX I

Test	Manu-facturer	Bolt Type	Diam. (in)	Test Data Pullout (K)	EPRI Overall Mean (K)	RATIO	
K	WEJ-IT	STUD	1.000	9.98	20.85	0.48	2 Tests in 56 <= 0.50
K	WEJ-IT	STUD	0.625	4.69	9.51	0.49	
K	WEJ-IT	STUD	0.500	3.47	6.87	0.51	
K	WEJ-IT	STUD	1.000	10.70	20.85	0.51	
K	WEJ-IT	STUD	0.500	3.73	6.87	0.54	
T	WEJ-IT	STUD	0.500	3.74	6.87	0.54	
K	WEJ-IT	STUD	0.375	2.39	4.39	0.54	
K	WEJ-IT	STUD	0.375	2.39	4.39	0.54	
K	WEJ-IT	STUD	0.500	3.88	6.87	0.56	
K	WEJ-IT	STUD	1.000	11.79	20.85	0.57	
K	WEJ-IT	STUD	0.375	2.51	4.39	0.57	
T	WEJ-IT	STUD	0.500	3.98	6.87	0.58	
K	WEJ-IT	STUD	1.000	12.15	20.85	0.58	
K	WEJ-IT	STUD	0.375	2.59	4.39	0.59	
K	WEJ-IT	STUD	0.750	8.35	14.07	0.59	
K	WEJ-IT	STUD	0.375	2.63	4.39	0.60	
K	WEJ-IT	STUD	0.500	4.16	6.87	0.61	
K	WEJ-IT	STUD	0.375	2.67	4.39	0.61	
T	WEJ-IT	STUD	0.500	4.18	6.87	0.61	
K	WEJ-IT	STUD	1.000	12.75	20.85	0.61	
K	WEJ-IT	STUD	0.375	2.72	4.39	0.62	
T	WEJ-IT	STUD	1.000	12.94	20.85	0.62	
K	WEJ-IT	STUD	0.625	5.91	9.51	0.62	
K	WEJ-IT	STUD	0.750	8.75	14.07	0.62	
K	WEJ-IT	STUD	0.500	4.28	6.87	0.62	
K	WEJ-IT	STUD	0.500	4.29	6.87	0.62	
K	WEJ-IT	STUD	0.500	4.29	6.87	0.62	
K	WEJ-IT	STUD	0.750	8.95	14.07	0.64	
K	WEJ-IT	STUD	0.750	8.95	14.07	0.64	
K	WEJ-IT	STUD	0.750	8.95	14.07	0.64	
K	WEJ-IT	STUD	0.750	8.95	14.07	0.64	
K	WEJ-IT	STUD	0.625	6.11	9.51	0.64	
K	WEJ-IT	STUD	0.625	6.11	9.51	0.64	
K	WEJ-IT	STUD	0.750	9.16	14.07	0.65	
K	WEJ-IT	STUD	0.500	4.49	6.87	0.65	
K	WEJ-IT	STUD	0.625	6.31	9.51	0.66	
K	WEJ-IT	STUD	0.625	6.32	9.51	0.66	
K	WEJ-IT	STUD	0.750	9.36	14.07	0.67	
K	WEJ-IT	STUD	0.750	9.36	14.07	0.67	
T	WEJ-IT	STUD	1.000	14.02	20.85	0.67	
K	WEJ-IT	STUD	0.500	4.69	6.87	0.68	
K	WEJ-IT	STUD	0.625	6.52	9.51	0.69	
K	WEJ-IT	STUD	0.750	9.77	14.07	0.69	
T	WEJ-IT	STUD	1.000	14.73	20.85	0.71	

APPENDIX I

Test	Manu-facturer	Bolt Type	Diam. (in)	Test Data Pullout (K)	EPRI Overall Mean (K)	RATIO
K	WEJ-IT	STUD	1.000	14.81	20.85	0.71
K	WEJ-IT	STUD	0.500	4.90	6.87	0.71
K	WEJ-IT	STUD	0.625	6.92	9.51	0.73
K	WEJ-IT	STUD	0.625	6.92	9.51	0.73
K	WEJ-IT	STUD	0.375	3.20	4.39	0.73
K	WEJ-IT	STUD	0.625	7.13	9.51	0.75
K	WEJ-IT	STUD	0.375	3.32	4.39	0.76
K	WEJ-IT	STUD	0.375	3.52	4.39	0.80
K	WEJ-IT	STUD	1.000	17.31	20.85	0.83
K	WEJ-IT	STUD	1.000	18.92	20.85	0.91
K	WEJ-IT	STUD	1.000	19.27	20.85	0.92
K	WEJ-IT	STUD	1.000	19.48	20.85	0.93

APPENDIX I

Test	Manu-facturer	Bolt Type	Diam. (in)	Test Data Pullout (K)	EPRI Overall Mean (K)	RATIO	
K	WEJ-IT	WEDGE	0.375	1.03	4.39	0.23	2 Tests in 63 <= 0.26
K	WEJ-IT	WEDGE	0.750	3.61	14.07	0.26	
T	WEJ-IT	WEDGE	0.500	2.06	6.87	0.30	
K	WEJ-IT	WEDGE	0.625	3.27	9.51	0.34	
T	WEJ-IT	WEDGE	0.500	2.39	6.87	0.35	
K	WEJ-IT	WEDGE	0.875	6.52	18.28	0.36	
K	WEJ-IT	WEDGE	0.375	1.57	4.39	0.36	
K	WEJ-IT	WEDGE	0.625	3.47	9.51	0.36	
K	WEJ-IT	WEDGE	0.625	3.47	9.51	0.36	
K	WEJ-IT	WEDGE	0.500	2.51	6.87	0.37	
K	WEJ-IT	WEDGE	0.500	2.51	6.87	0.37	
K	WEJ-IT	WEDGE	0.500	2.61	6.87	0.38	
K	WEJ-IT	WEDGE	0.500	2.66	6.87	0.39	
K	WEJ-IT	WEDGE	0.875	7.13	18.28	0.39	
K	WEJ-IT	WEDGE	0.750	5.50	14.07	0.39	
K	WEJ-IT	WEDGE	0.750	5.50	14.07	0.39	
K	WEJ-IT	WEDGE	0.500	2.72	6.87	0.40	
T	WEJ-IT	WEDGE	0.500	2.79	6.87	0.41	
K	WEJ-IT	WEDGE	0.625	3.88	9.51	0.41	
K	WEJ-IT	WEDGE	0.375	1.80	4.39	0.41	
K	WEJ-IT	WEDGE	0.750	5.91	14.07	0.42	
K	WEJ-IT	WEDGE	0.500	2.92	6.87	0.43	
K	WEJ-IT	WEDGE	0.625	4.08	9.51	0.43	
K	WEJ-IT	WEDGE	0.625	4.08	9.51	0.43	
K	WEJ-IT	WEDGE	0.625	4.08	9.51	0.43	
K	WEJ-IT	WEDGE	0.375	1.89	4.39	0.43	
K	WEJ-IT	WEDGE	0.375	1.90	4.39	0.43	
K	WEJ-IT	WEDGE	0.750	6.11	14.07	0.43	
K	WEJ-IT	WEDGE	0.750	6.11	14.07	0.43	
K	WEJ-IT	WEDGE	0.500	3.04	6.87	0.44	
K	WEJ-IT	WEDGE	0.750	6.31	14.07	0.45	
K	WEJ-IT	WEDGE	0.750	6.31	14.07	0.45	
K	WEJ-IT	WEDGE	0.375	1.97	4.39	0.45	
K	WEJ-IT	WEDGE	0.375	1.97	4.39	0.45	
K	WEJ-IT	WEDGE	0.750	6.32	14.07	0.45	
K	WEJ-IT	WEDGE	0.625	4.28	9.51	0.45	
K	WEJ-IT	WEDGE	0.500	3.12	6.87	0.45	
K	WEJ-IT	WEDGE	0.500	3.12	6.87	0.45	
K	WEJ-IT	WEDGE	0.875	8.34	18.28	0.46	
K	WEJ-IT	WEDGE	0.875	8.34	18.28	0.46	
K	WEJ-IT	WEDGE	0.875	8.34	18.28	0.46	
K	WEJ-IT	WEDGE	0.875	8.34	18.28	0.46	
K	WEJ-IT	WEDGE	0.625	4.49	9.51	0.47	
K	WEJ-IT	WEDGE	0.375	2.17	4.39	0.49	

APPENDIX I

Test	Manu-facturer	Bolt Type	Diam. (in)	Test Data Pullout (K)	EPRI Overall Mean (K)	RATIO
K	WEJ-IT	WEDGE	0.875	9.16	18.28	0.50
K	WEJ-IT	WEDGE	0.750	7.13	14.07	0.51
K	WEJ-IT	WEDGE	1.000	10.59	20.85	0.51
K	WEJ-IT	WEDGE	1.000	11.02	20.85	0.53
K	WEJ-IT	WEDGE	1.000	11.02	20.85	0.53
K	WEJ-IT	WEDGE	0.375	2.33	4.39	0.53
K	WEJ-IT	WEDGE	0.875	9.77	18.28	0.53
K	WEJ-IT	WEDGE	1.000	11.24	20.85	0.54
K	WEJ-IT	WEDGE	0.875	9.97	18.28	0.55
K	WEJ-IT	WEDGE	1.000	11.89	20.85	0.57
K	WEJ-IT	WEDGE	1.000	11.89	20.85	0.57
K	WEJ-IT	WEDGE	0.625	5.50	9.51	0.58
K	WEJ-IT	WEDGE	0.500	4.03	6.87	0.59
K	WEJ-IT	WEDGE	0.375	2.62	4.39	0.60
K	WEJ-IT	WEDGE	0.875	10.98	18.28	0.60
K	WEJ-IT	WEDGE	1.000	13.62	20.85	0.65
K	WEJ-IT	WEDGE	1.000	13.62	20.85	0.65
K	WEJ-IT	WEDGE	1.000	13.84	20.85	0.66
K	WEJ-IT	WEDGE	1.000	14.49	20.85	0.69

APPENDIX I

Test	Manu-facturer	Bolt Type	Diam. (in)	Test Data Pullout (K)	EPRI Overall Mean (K)	RATIO	
K	HILTI	HXSLV	0.375	1.30	4.39	0.30	1 Test in 13 <= 0.30
K	HILTI	HXSLV	0.375	1.68	4.39	0.38	
K	HILTI	HXSLV	0.375	1.77	4.39	0.40	
K	HILTI	HXSLV	0.375	1.87	4.39	0.43	
K	HILTI	HXSLV	0.375	2.01	4.39	0.46	
K	HILTI	HXSLV	0.375	2.01	4.39	0.46	
T	HILTI	SLEEVE	0.375	2.37	4.39	0.54	
K	HILTI	HXSLV	0.375	2.63	4.39	0.60	
K	HILTI	HXSLV	0.375	2.70	4.39	0.62	
K	HILTI	HXSLV	0.375	2.93	4.39	0.67	
K	HILTI	HXSLV	0.375	3.38	4.39	0.77	
T	HILTI	SLEEVE	0.375	3.50	4.39	0.80	
T	HILTI	SLEEVE	0.375	3.89	4.39	0.89	
K	HILTI	HXSLV	0.500	1.75	6.87	0.25	See Text
K	HILTI	HXSLV	0.500	3.07	6.87	0.45	
K	HILTI	HXSLV	0.625	5.10	9.51	0.54	1 Test in 16 <= 0.54
K	HILTI	HXSLV	0.625	5.30	9.51	0.56	
K	HILTI	HXSLV	0.625	5.91	9.51	0.62	
K	HILTI	HXSLV	0.625	5.91	9.51	0.62	
K	HILTI	HXSLV	0.500	4.29	6.87	0.62	
K	HILTI	HXSLV	0.500	4.43	6.87	0.64	
K	HILTI	HXSLV	0.500	4.43	6.87	0.64	
K	HILTI	HXSLV	0.625	6.52	9.51	0.69	
K	HILTI	HXSLV	0.625	6.52	9.51	0.69	
K	HILTI	HXSLV	0.500	4.89	6.87	0.71	
K	HILTI	HXSLV	0.625	7.13	9.51	0.75	
K	HILTI	HXSLV	0.500	5.24	6.87	0.76	
K	HILTI	HXSLV	0.500	5.61	6.87	0.82	
K	HILTI	HXSLV	0.500	5.91	6.87	0.86	
K	HILTI	HXSLV	0.500	5.95	6.87	0.87	
K	HILTI	HXSLV	0.625	8.55	9.51	0.90	

APPENDIX II

Test	Manu-facturer	Bolt Type	Diam. (in)	Test Data Pullout (K)	
K	STAR	STEEL	0.375	2.21	> 1.65 K
K	STAR	STEEL	0.375	2.21	
K	STAR	STEEL	0.375	2.51	
K	STAR	STEEL	0.375	2.71	
K	STAR	STEEL	0.375	2.73	
K	STAR	STEEL	0.375	2.99	
K	STAR	STEEL	0.375	3.08	
K	STAR	STEEL	0.375	3.12	
K	STAR	STEEL	0.375	3.25	
K	STAR	STEEL	0.375	3.25	
K	STAR	STEEL	0.500	5.10	> 2.58 K
K	STAR	STEEL	0.500	5.10	
K	STAR	STEEL	0.500	5.10	
K	STAR	STEEL	0.500	5.10	
K	STAR	STEEL	0.500	5.10	
K	STAR	STEEL	0.500	5.50	
K	STAR	STEEL	0.500	5.91	
K	STAR	STEEL	0.500	6.11	
K	STAR	STEEL	0.500	6.15	
K	STAR	STEEL	0.500	6.32	
K	STAR	STEEL	0.625	7.94	> 3.57 K
K	STAR	STEEL	0.625	7.94	
K	STAR	STEEL	0.625	8.34	
K	STAR	STEEL	0.625	8.34	
K	STAR	STEEL	0.625	8.34	
K	STAR	STEEL	0.625	8.75	
K	STAR	STEEL	0.625	8.95	
K	STAR	STEEL	0.625	8.95	
K	STAR	STEEL	0.625	8.95	
K	STAR	STEEL	0.625	9.56	
K	STAR	STEEL	0.750	5.30	> 5.28 K
K	STAR	STEEL	0.750	6.72	
K	STAR	STEEL	0.750	7.94	
K	STAR	STEEL	0.750	8.34	
K	STAR	STEEL	0.750	8.55	
K	STAR	STEEL	0.750	8.55	
K	STAR	STEEL	0.750	8.75	
K	STAR	STEEL	0.750	8.95	
K	STAR	STEEL	0.750	9.12	
K	STAR	STEEL	0.750	9.56	

APPENDIX II

Test	Manu-facturer	Bolt Type	Diam. (in)	Test Data Pullout (K)	
K	STAR	STUD	0.375	2.07	> 1.65 K
K	STAR	STUD	0.375	2.31	
K	STAR	STUD	0.375	2.35	
K	STAR	STUD	0.375	2.39	
K	STAR	STUD	0.375	2.39	
K	STAR	STUD	0.375	2.66	
K	STAR	STUD	0.375	2.71	
K	STAR	STUD	0.375	2.71	
K	STAR	STUD	0.375	2.88	
K	STAR	STUD	0.375	3.12	
K	STAR	STUD	0.500	2.89	> 2.58 K
K	STAR	STUD	0.500	3.21	
K	STAR	STUD	0.500	3.27	
K	STAR	STUD	0.500	3.66	
K	STAR	STUD	0.500	3.88	
K	STAR	STUD	0.500	4.04	
K	STAR	STUD	0.500	4.04	
K	STAR	STUD	0.500	4.08	
T	STAR	STUD	0.500	4.09	
K	STAR	STUD	0.500	4.42	
K	STAR	STUD	0.500	4.42	
T	STAR	STUD	0.500	5.51	
T	STAR	STUD	0.500	5.78	
K	STAR	STUD	0.625	6.52	> 3.57 K
K	STAR	STUD	0.625	6.52	
K	STAR	STUD	0.625	6.72	
K	STAR	STUD	0.625	6.92	
K	STAR	STUD	0.625	7.94	
K	STAR	STUD	0.625	7.94	
K	STAR	STUD	0.625	8.35	
K	STAR	STUD	0.625	8.55	
K	STAR	STUD	0.625	8.75	
K	STAR	STUD	0.750	9.83	> 5.28 K
K	STAR	STUD	0.750	9.92	
K	STAR	STUD	0.750	10.98	
K	STAR	STUD	0.750	10.98	
K	STAR	STUD	0.750	10.98	
K	STAR	STUD	0.750	10.98	
K	STAR	STUD	0.750	11.19	
K	STAR	STUD	0.750	11.19	
K	STAR	STUD	0.750	11.59	
K	STAR	STUD	0.750	11.79	

APPENDIX II

Test	Manu-facturer	Bolt Type	Diam. (in)	Test Data Pullout (K)	
K	WEJ-IT	STUD	0.375	2.39	> 1.65 K
K	WEJ-IT	STUD	0.375	2.39	
K	WEJ-IT	STUD	0.375	2.51	
K	WEJ-IT	STUD	0.375	2.59	
K	WEJ-IT	STUD	0.375	2.63	
K	WEJ-IT	STUD	0.375	2.67	
K	WEJ-IT	STUD	0.375	2.72	
K	WEJ-IT	STUD	0.375	3.20	
K	WEJ-IT	STUD	0.375	3.32	
K	WEJ-IT	STUD	0.375	3.52	
K	WEJ-IT	STUD	0.500	3.47	> 2.58 K
K	WEJ-IT	STUD	0.500	3.73	
T	WEJ-IT	STUD	0.500	3.74	
K	WEJ-IT	STUD	0.500	3.88	
T	WEJ-IT	STUD	0.500	3.98	
K	WEJ-IT	STUD	0.500	4.16	
T	WEJ-IT	STUD	0.500	4.18	
K	WEJ-IT	STUD	0.500	4.28	
K	WEJ-IT	STUD	0.500	4.29	
K	WEJ-IT	STUD	0.500	4.29	
K	WEJ-IT	STUD	0.500	4.49	
K	WEJ-IT	STUD	0.500	4.69	
K	WEJ-IT	STUD	0.500	4.90	
K	WEJ-IT	STUD	0.625	4.69	> 3.57 K
K	WEJ-IT	STUD	0.625	5.91	
K	WEJ-IT	STUD	0.625	6.11	
K	WEJ-IT	STUD	0.625	6.11	
K	WEJ-IT	STUD	0.625	6.31	
K	WEJ-IT	STUD	0.625	6.32	
K	WEJ-IT	STUD	0.625	6.52	
K	WEJ-IT	STUD	0.625	6.92	
K	WEJ-IT	STUD	0.625	6.92	
K	WEJ-IT	STUD	0.625	7.13	
K	WEJ-IT	STUD	0.750	8.35	> 5.28 K
K	WEJ-IT	STUD	0.750	8.75	
K	WEJ-IT	STUD	0.750	8.95	
K	WEJ-IT	STUD	0.750	8.95	
K	WEJ-IT	STUD	0.750	8.95	
K	WEJ-IT	STUD	0.750	8.95	
K	WEJ-IT	STUD	0.750	9.16	
K	WEJ-IT	STUD	0.750	9.36	
K	WEJ-IT	STUD	0.750	9.36	
K	WEJ-IT	STUD	0.750	9.77	

APPENDIX II

Test	Manu-facturer	Bolt Type	Diam. (in)	Test Data Pullout (K)	
K	WEJ-IT	STUD	1.000	9.98	> 7.82 K
K	WEJ-IT	STUD	1.000	10.70	
K	WEJ-IT	STUD	1.000	11.79	
K	WEJ-IT	STUD	1.000	12.15	
K	WEJ-IT	STUD	1.000	12.75	
T	WEJ-IT	STUD	1.000	12.94	
T	WEJ-IT	STUD	1.000	14.02	
T	WEJ-IT	STUD	1.000	14.73	
K	WEJ-IT	STUD	1.000	14.81	
K	WEJ-IT	STUD	1.000	17.31	
K	WEJ-IT	STUD	1.000	18.92	
K	WEJ-IT	STUD	1.000	19.27	
K	WEJ-IT	STUD	1.000	19.48	

APPENDIX II

Test	Manu-facturer	Bolt Type	Diam. (in)	Test Data Pullout (K)	
K	WEJ-IT	WEDGE	0.375	1.03	< 1.10 K
K	WEJ-IT	WEDGE	0.375	1.57	
K	WEJ-IT	WEDGE	0.375	1.80	
K	WEJ-IT	WEDGE	0.375	1.89	
K	WEJ-IT	WEDGE	0.375	1.90	
K	WEJ-IT	WEDGE	0.375	1.97	
K	WEJ-IT	WEDGE	0.375	1.97	
K	WEJ-IT	WEDGE	0.375	2.17	
K	WEJ-IT	WEDGE	0.375	2.33	
K	WEJ-IT	WEDGE	0.375	2.62	
T	WEJ-IT	WEDGE	0.500	2.06	> 1.72 K
T	WEJ-IT	WEDGE	0.500	2.39	
K	WEJ-IT	WEDGE	0.500	2.51	
K	WEJ-IT	WEDGE	0.500	2.51	
K	WEJ-IT	WEDGE	0.500	2.61	
K	WEJ-IT	WEDGE	0.500	2.66	
K	WEJ-IT	WEDGE	0.500	2.72	
T	WEJ-IT	WEDGE	0.500	2.79	
K	WEJ-IT	WEDGE	0.500	2.92	
K	WEJ-IT	WEDGE	0.500	3.04	
K	WEJ-IT	WEDGE	0.500	3.12	
K	WEJ-IT	WEDGE	0.500	3.12	
K	WEJ-IT	WEDGE	0.500	4.03	
K	WEJ-IT	WEDGE	0.625	3.27	> 2.38 K
K	WEJ-IT	WEDGE	0.625	3.47	
K	WEJ-IT	WEDGE	0.625	3.47	
K	WEJ-IT	WEDGE	0.625	3.88	
K	WEJ-IT	WEDGE	0.625	4.08	
K	WEJ-IT	WEDGE	0.625	4.08	
K	WEJ-IT	WEDGE	0.625	4.08	
K	WEJ-IT	WEDGE	0.625	4.28	
K	WEJ-IT	WEDGE	0.625	4.49	
K	WEJ-IT	WEDGE	0.625	5.50	
K	WEJ-IT	WEDGE	0.750	3.61	> 3.52 K
K	WEJ-IT	WEDGE	0.750	5.50	
K	WEJ-IT	WEDGE	0.750	5.50	
K	WEJ-IT	WEDGE	0.750	5.91	
K	WEJ-IT	WEDGE	0.750	6.11	
K	WEJ-IT	WEDGE	0.750	6.11	
K	WEJ-IT	WEDGE	0.750	6.31	
K	WEJ-IT	WEDGE	0.750	6.31	
K	WEJ-IT	WEDGE	0.750	6.32	
K	WEJ-IT	WEDGE	0.750	7.13	

APPENDIX II

Test	Manu-facturer	Bolt Type	Diam. (in)	Test Data Pullout (K)	
K	WEJ-IT	WEDGE	0.875	6.52	> 4.57 K
K	WEJ-IT	WEDGE	0.875	7.13	
K	WEJ-IT	WEDGE	0.875	8.34	
K	WEJ-IT	WEDGE	0.875	8.34	
K	WEJ-IT	WEDGE	0.875	8.34	
K	WEJ-IT	WEDGE	0.875	8.34	
K	WEJ-IT	WEDGE	0.875	9.16	
K	WEJ-IT	WEDGE	0.875	9.77	
K	WEJ-IT	WEDGE	0.875	9.97	
K	WEJ-IT	WEDGE	0.875	10.98	
K	WEJ-IT	WEDGE	1.000	10.59	> 5.21 K
K	WEJ-IT	WEDGE	1.000	11.02	
K	WEJ-IT	WEDGE	1.000	11.02	
K	WEJ-IT	WEDGE	1.000	11.24	
K	WEJ-IT	WEDGE	1.000	11.89	
K	WEJ-IT	WEDGE	1.000	11.89	
K	WEJ-IT	WEDGE	1.000	13.62	
K	WEJ-IT	WEDGE	1.000	13.62	
K	WEJ-IT	WEDGE	1.000	13.84	
K	WEJ-IT	WEDGE	1.000	14.49	

APPENDIX II

Test	Manu-facturer	Bolt Type	Diam. (in)	Test Data Pullout (K)	
K	HILTI	HXSLV	0.375	1.30	> 1.10 K
K	HILTI	HXSLV	0.375	1.68	
K	HILTI	HXSLV	0.375	1.77	
K	HILTI	HXSLV	0.375	1.87	
K	HILTI	HXSLV	0.375	2.01	
K	HILTI	HXSLV	0.375	2.01	
T	HILTI	SLEEVE	0.375	2.37	
K	HILTI	HXSLV	0.375	2.63	
K	HILTI	HXSLV	0.375	2.70	
K	HILTI	HXSLV	0.375	2.93	
K	HILTI	HXSLV	0.375	3.38	
T	HILTI	SLEEVE	0.375	3.50	
T	HILTI	SLEEVE	0.375	3.89	
K	HILTI	HXSLV	0.500	1.75	< 2.58 K
K	HILTI	HXSLV	0.500	3.07	
K	HILTI	HXSLV	0.500	4.29	
K	HILTI	HXSLV	0.500	4.43	
K	HILTI	HXSLV	0.500	4.43	
K	HILTI	HXSLV	0.500	4.89	
K	HILTI	HXSLV	0.500	5.24	
K	HILTI	HXSLV	0.500	5.61	
K	HILTI	HXSLV	0.500	5.91	
K	HILTI	HXSLV	0.500	5.95	
K	HILTI	HXSLV	0.625	5.10	> 3.57 K
K	HILTI	HXSLV	0.625	5.30	
K	HILTI	HXSLV	0.625	5.91	
K	HILTI	HXSLV	0.625	5.91	
K	HILTI	HXSLV	0.625	6.52	
K	HILTI	HXSLV	0.625	6.52	
K	HILTI	HXSLV	0.625	7.13	
K	HILTI	HXSLV	0.625	8.55	

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